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A Study of Cusp Magnetic Field Effect on IEC Device

IEC装置におけるカスプ磁界の研究

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The inertial electrostatic confinement (IEC) device is a compact neutron source. The neutron production rate (NPR) of IEC device is insufficient for applications like boron neutron capture therapy and it is necessary to increase NPR. To increase NPR, cusp magnetic field is applied in the cylindrical IEC device. In previous research, NPR is increased up to 133%, but not evaluated from the physical aspects. In order to confirm the effect of the magnetic field, we measured the spectra profile of Hα line. The spectra profile is a little different from those obtained in previous research. We will measure the spectra more accurately and get the ion energy distribution with and without cusp magnetic field.

1. Introduction

Inertial Electrostatic Confinement (IEC) device is a compact neutron source. The IEC device consists of a vacuum chamber and two electrodes (Fig. 1): outer electrode is the anode and inner electrode is the cathode.

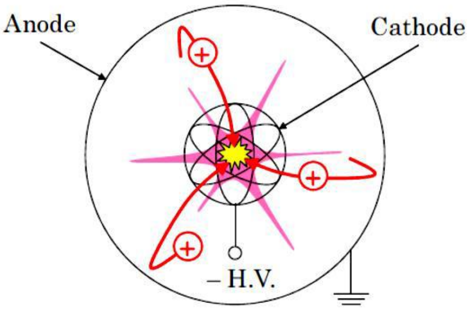

Fig. 1 Schematic of Inertial Electrostatic Confinement Fusion device

Deuterium is filled in the vacuum chamber and negative high voltage is applied to the cathode. Then, deuterium causes following nuclear reactions emitting neutrons [1].

$$\mathrm{D} + \mathrm{D} \rightarrow {}^{3}\mathrm{He} + \mathrm{n}\ (2.45\ \mathrm{MeV})$$

$$\mathrm{D} + \mathrm{D} \rightarrow \mathrm{T} + \mathrm{p}\ (3.03\ \mathrm{MeV})$$

Now, more effective utilization of neutrons is expected [2] and to realize it, potential well in the cathodes [3], increment of fusion reaction, etc. have been studied [4-7].

Neutron Production Rate (NPR) of the IEC device is lower than other neutron source such as a fission reactor and therefore the increase of NPR is a concern in IEC device research [7].

2. Experimental Device

We developed a Cylindrical IEC device with azimuthal cusp magnetic field (Fig. 2) [8-9]. In general, the spherical IEC device is studied. However cylindrical one is of great advantage to spherical one. It is necessary to increase ion density to increase NPR. To realize it, the deformation of electric potential distribution must be minimized. The deformation of cylindrical one is better than that of spherical one because its feedthrough is small than the size of the device.

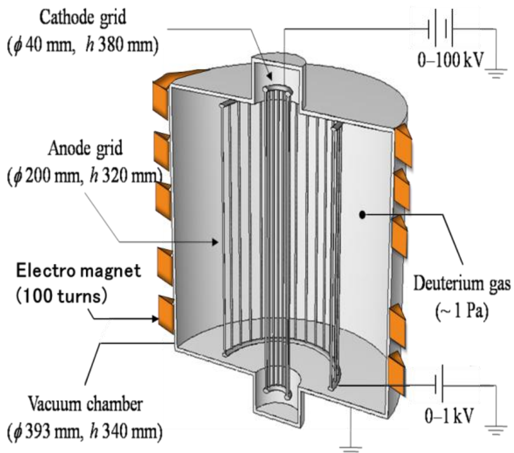

Fig. 2 Cylindrical IEC device

To increase ion density, cusp magnetic field is applied by magnetic coils turned around the device as shown in Fig. 2. Cusp magnetic field can trap electrons near the anode and they produce ions there. Because the potential is high near the anode and the generated ions may have high energy, thus they can cause nuclear fusion reactions effectively. Previous research showed that NPR is increased up to 133 % and predicted that ions may be generated near the anode. For the confirmation, we will measure the ion energy obtained in cusp magnetic field configuration.

3. Experiment

In general, deuterium is used for fusion in IEC device. However, in this spectroscopic experiment, light hydrogen is used. Light hydrogen moves in the same way as deuterium and causes following reaction,

$$H^{+}(E) + H \rightarrow H^{*}(E) + H^{+}$$

where E means the kinetic energy of incident ion. Kinetic energy after reaction is allocated to particles in proportion to their masses. In this study, it is assumed that the excited particle after collision moves in the same direction as the ion before collision. The excited particle emits the light with a wavelength of 656 nm, Hβ line. The particle moves and the spectrum occurs Doppler shift. The speeds, energy of ions are measured by the speed of neutral particle because of following emission and equation ,

$$H^{*}(E) \rightarrow H(E) + h\nu$$

$$\lambda = \left(1 + \frac{v}{c}\right)\lambda_0 \tag{1}$$

where λ means the wavelength emitted by H^{*}, v means the velocity of H^{*}, c means the light speed, λ_0 means the original spectral wavelength.

Spectroscopic measurement uses biconvex lens, optical fiber, monochrometer and analysis software ATRAS for Windows Ver2.4.

4. Results

The obtained spectral profile, of Hα line is shown in Fig. 3. The exposure time of monochrometer is 0.1 second and cumulated number is 1000 times.

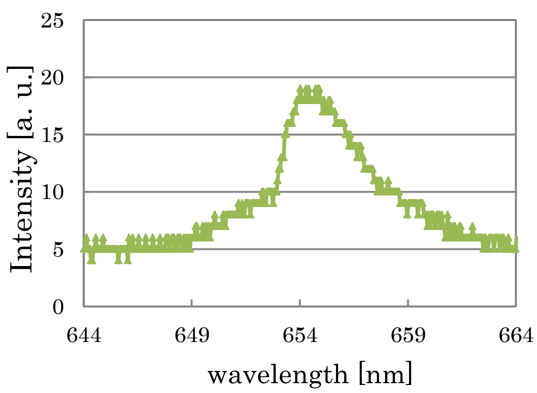

Fig. 3 The spectral profile of Hα line at the center of the cylindrical IEC device (-30 kV, 20 mA)

Other spectral lines, such as Hβ, Hγ and Hδ lines are not obtained well because their S/N ratio is low.

5. Summary

To increase NPR, cusp magnetic field is applied to the cylindrical IEC device in previous research. To confirm the ion energy with and without cusp magnetic field and to compare their results, fist the Hα line emitted by discharge plasma in the device without cusp magnetic field is measured.

6. Future Plan

To increase the S/N ratio of line profile measurement, the measurement system should be improved. Then, the spectral profile with respect to the voltage, current and distance from the center of the device is going to be measured, and the ion energy is going to be calculated from those results. Finally, the ion energy with cusp magnetic field is going to be measured and compared.

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